INAUGURAL ADDRESS

OF

C. W. SIEMENS, D.C.L., F.R.S.,

THE PRESIDENT OF THE IRON AND STEEL INSTITUTE.

Delivered at Annual General Meeting of Iron and Steel Institute, held in London, March, 1877.

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The Iron and Steel Institute was called into existence in 1869 by a few of those leading members, who, assisted throughout by our energetic General Secretary, are still giving it their zealous and disinterested support. At their head stood his Grace the Duke of Devonshire, who, as its first President, pointed out to the young Society the useful results that would be realized through a judicious combination of natural science with practical experience, and by attention to the progress in metallurgical processes effected in other countries. He thus implanted upon this Institute a vitality which has resulted in a rapid increase of its members, and a career of usefulness such as scarcely any other society for the promotion of applied science can boast of.

With regard to the progress of the Institute, in the numerical strength of its membership, the number has risen from 292 in 1869, to 960 in 1876, and the proposals of candidates coming in show that the interest in the society has not abated. This numerical progress, however, cannot be expected to continue, because the Institute has now arrived at a point where it counts among its members those gentlemen who can best aid us in the objects we have in view, and it can thus afford to restrict the privilege of membership to candidates, who by their previous training, and actual position, have qualified themselves to join profitably in our discussions.

During last year, as the report shows, meetings were held in London and Leeds, at which numerous papers were brought before you regarding subjects of considerable interest, and which gave rise to important discussions.

But besides the reading and discussion of papers, there has been

much other useful work done by the Institute; I refer to the special committees that have on various occasions been appointed by the Council for the purpose of investigating questions of importance relative to the production of iron and steel, and the interest evinced in those special enquiries proves how much more may yet be accomplished by more systematic organisation for the attainment of similar objects.

Another branch of useful action of this Institute has been to place before the members, through its JOURNAL, the latest results obtained in other countries, which work was ably performed by our late Foreign Secretary, Mr. David Forbes, F.R.S. The death of this distinguished gentleman must be a matter of deep regret to every member of the Institute.

Out of our still young society has grown another—the British Iron Trade Association—which, under the able presidency of Mr. Geo. T. Clark, already gives promise of useful results in supplying us with reliable statistics, regarding the extent and progress of the iron trade of this and other countries, and in calling the attention of our legislators to questions of tariffs, and to other measures, likely to affect the interests of the British iron trade.

Educational.—Intimately connected with the interests of this Institution, and with the prosperity of the iron trade, is the subject of technical education. It is not many years since *practical* knowledge was regarded as the one thing requisite in an iron smelter, whilst *theoretical* knowledge of the chemical and mechanical principles involved in the operations was viewed with considerable suspicion. The aversion to scientific reasoning upon metallurgical processes extended even to the authors who professed to enlighten us upon these subjects; and we find, in technological works of the early part of the present century, little more than eye-witness accounts of the processes pursued by the operating smelter, and no attempt to reconcile those operations with scientific facts. A great step in advance was made in this country by Dr. Percy, when, in 1864, he published his remarkable "Metallurgy of Iron and Steel." Here we find the gradual processes of iron smelting passed in review, and supported by chemical analyses of the fuel, ores, and fluxing materials employed, and of the metal, slags, and cinder produced in the operation. On the continent of Europe, the researches of

Ebelmann, and the technological writings of Karsten, Tunner, Grüner, Karl, Åkermann, Wedding, and others, have also contributed largely towards a more rational conception of the processes employed in iron smelting.

It must be conceded to the nations of the Continent of Europe that they were the first to recognize the necessity of technical education, and it has been chiefly in consequence of their increasing competition with the producers of this country, that the attention of the latter has been forcibly drawn to this subject. The only special educational establishment for the metallurgist of Great Britain is the School of Mines. This institution has unquestionably already produced most excellent results in furnishing us with young metallurgists, qualified to make good careers for themselves, and to advance the practical processes of iron making; but it is equally evident that that institution is still susceptible of great improvement, by adding to the branches of knowledge now taught at Jermyn Street, and I cannot help thinking that a step in the wrong direction has recently been made in separating geographically and administratively the instruction in pure chemistry from that in applied chemistry, geology, and mineralogy. If properly supported, the School of Mines might become one of the best and largest institutions of its kind, but it would be an error to suppose that, however successful it might be, it could be made to suffice for the requirements of the whole country. Other similar institutions will have to be opened in provincial centres, and we have an excellent example set us by the town of Manchester, which, in creating its Owen's College, has laid the foundation for a technical university, capable of imparting useful knowledge to the technologist of the future.

Technical education is here spoken of in contradistinction to the purely classic and scientific education of the Universities, but it must not be supposed that I would advocate any attempt at comprising in its curriculum a practical working of the processes which the student would have to direct in after-life. This has been attempted at many of the polytechnic schools of the Continent with results decidedly unfavourable to the useful career of the student; the practice taught in such establishments is devoid of the commercial element, and must of necessity be objectionable

as tending to engender conceit in the mind of the student, which will stand in the way of the unbiassed application of his mind to real work. Let technical schools confine themselves to teaching those natural sciences which bear upon practice, but let practice itself be taught in the workshop and in the metallurgical establishment.

Labour.—Equal in importance to an enlightened direction of metallurgical works, is the obtaining of labour upon reasonable terms. The wages paid in this country are, as a rule, higher than those prevailing on the Continent of Europe, and I do not belong to those who would wish to see them materially reduced. The late Mr. Brassey found as the result of his experience that the cost of labour, that is the co-efficient resulting from the division of the work done per day, by the day's wage, was a constant quantity for all countries. This rule would lead to the conclusion that the more costly but effective labour, as measured by a day's wage, must be the cheaper in the end, because it produces a greater result with a given amount of plant. I have no reason to doubt the general truth of this proposition, provided only that it is not disturbed by misconceptions, regarding the supposed antagonism between labour, and the capital and skill directing it, which misconceptions have exercised a baneful influence upon the industries of this and other countries in recent times. Both employer and employed have reason to reflect seriously upon the experience gained during the late period of high prices. Whilst employers added largely to their producing plant, and acquired additional colliery and mining property in order to increase their output, and so took advantage, unwisely I think, of the temporary inflation, it can hardly be considered a matter for surprise, that the working classes caught up the feverish excitement, and endeavoured to obtain their share of the golden fruits that were supposed to accrue to their employers. Scarcity of labour was naturally suggestive of combination, and high rates of wages supplied the means of imposing onerous conditions upon the employer, whereby the development of economical processes was effectually retarded.

The commercial crisis which ensued has rendered the depression more general and more sweeping than could have been reasonably expected, and now that we find ourselves at what we hope may be

regarded as the extreme ebb of the ever-fluctuating tide of prosperity, it behoves us to consider carefully how a recurrence of the same causes of mischief may in the future be rendered less dangerous in their results.

One of the most effectual methods of attaining this important result would consist in establishing the relations between employers and employed upon the basis of mutual interest. I hold that capital has its duties to perform as well as its rights to maintain, and that whilst the minimum of wages is that which enables the workman to live with reasonable comfort, both parties would be materially benefited by so arranging wages as to make them payable in great measure upon results, both as regards quality and quantity of work produced, whilst, by the establishment of mechanics' institutes, reading rooms, and mutual benefit associations, in connection with individual works, the feeling of community of interest would be further strengthened, and a recurrence of antagonistic action, so destructive to commercial results, might be avoided.

Fuel.—Next in importance to cheap, or rather to efficacious labour in the production of iron and steel, comes cheap fuel,—a subject to which, as you are aware, I have devoted considerable attention, and I would therefore treat it, with your permission, rather more fully than other subjects of perhaps equal importance. Fuel, in the widest acceptation of the word, may be said to comprise all potential force which we may call into requisition for effecting our purposes of heating and working the materials with which we have to deal, although in a more restricted sense it comprises only those carbonaceous matters which, in their combustion, yield the heat necessary for working our furnaces, and for raising steam in our boilers. It may safely be asserted that the great supply of energy available for our purposes has been, or is being, derived from that great orb which vivifies all nature—the sun. In the case of coal, it has been shown that its existence is attributable to the rays of the sun, which in former ages broke up or dissociated carbonic acid and water in the leaves of plants, and rendered the carbon and hydrogen, thus separated from the oxygen, available for re-combustion. The same action still continues in the formation of wood, peat, and indeed all vegetable matter.

The solar ray produces, however, other forms of energy through

the evaporation of sea water, and the resulting rainfall upon elevated lands, and through currents set up in the atmosphere and in the sea, which give rise to available sources of power of vast aggregate amount, and which may also be regarded in the light of fuel in the wider sense.

The form of fuel, however, which possesses the greatest interest for us, the iron smelters of the 19th century, is without doubt the accumulation of the solar energy of former ages, which is embodied in the form of coal, and it behoves us to inquire what are the stores of this most convenient form of fuel.

Recent enquiry into the distribution of coal in this and other countries has proved that the stores of these invaluable deposits are greater than had at one time been supposed.

I have compiled a table of the coal areas and production of the globe, the figures in which are collected from various sources. It is far from being complete, but will serve us for purposes of comparison.

THE COAL AREAS AND ANNUAL COAL PRODUCTION OF THE GLOBE.

	Area in Square Miles.	Production in 1874. Tons.
Great Britain	11,900	125,070,000
Germany	1,800	46,658,000
United States	192,000	50,000,000
France	1,800	17,060,000
Belgium	900	14,670,000
Austria	1,800	12,280,000
Russia	11,000	1,392,000
Nova Scotia, and adjoining Provinces	18,000	1,052,000
Spain	3,000	580,000
Other Countries	28,000	5,000,000
	270,200	274,262,000

This table shows roughly that the total area of the discovered coal fields of the world amount to 270,000 square miles.

It also appears that the total coal deposits of GreatBritian compare favourably with those of other European countries; but that both in the United States and in British North America, there exist deposits of extraordinary magnitude, which seem to promise a great future for the New World.

According to the report of the Coal Commissioners, published in 1871, there were then 90,207 million tons of coal available in Great Britain, at depths not greater than 4,000 feet, and in seams not less than 1 foot thick, besides a quantity of concealed coal estimated at 56,273 millions of tons, making a total of 146,480

millions. Since that period, there have been raised 600 millions of tons up to the close of 1875, leaving 145,880 millions of tons, which, at the present rate of consumption of nearly 132 millions of tons annually, would last 1,100 years. Statistics show that during the last 20 years there has been a mean annual increase in the output of about 3⅓ millions of tons, and a calculation made at this rate would give 250 years as the life of our coalfields.

In comparing, however, the above rate of increase with that of population and manufactures, it will be found that the additional coal consumption has not nearly kept pace with the increased demand for the effects of heat, the difference being ascribable to the introduction of economical processes in the application of fuel. In the case of the production of power, the economy effected in our best engines within the last 20 years exceeds 50 per cent., and an equally important saving has probably been realised in the production of iron and steel within the same period, as may be gathered from the fact that a ton of steel rails can now be produced from the ore with an expenditure not exceeding 55 cwt. of raw coal, whereas a ton of iron rails, 20 years ago, involved an expenditure exceeding 100 cwt. According to Dr. Percy, one large works consumed, in 1859, from 5 to 6 tons of coal per ton of rails. Statistics are unfortunately wanting to guide us respecting these important questions.

Considering the large margin for further improvement in almost every application of fuel, which can be shown upon theoretical grounds to exist, it seems not unreasonable to conclude that the ratio of increase of population and of output of manufactured goods will be nearly balanced, for many years to come, by the further introduction of economical processes, and that our annual production of coal will remain substantially the same within that period, which under those circumstances will probably be a period of comparatively cheap coal.

The above-mentioned speculation leads to the further conclusion that our coal supply at a workable depth will last for a period far exceeding the shorter estimated period of 250 years, especially if we take into account the probability of fresh discoveries, of which we have had recent instances, particularly in North Staffordshire, where a large area of coal and blackband ironstone is being opened up,

under the auspices of His Grace the Duke of Sutherland, by our member, Mr. Homer.

Wherever coalfields are found in Great Britain, they exist, generally speaking, under favourable circumstances. The deposits are for the most part met with at reasonable depths, the quality of the coal is unsurpassed by that of other countries, and although the coal and ironstone do not occur together in all the iron-producing districts, the distance from the coal to the iron is small, compared with that met with in other countries, and the insular position of Great Britain renders water carriage, both for internal communication and for the purpose of export, more readily available than elsewhere. These advantages ought to decide the present contest for supplying the markets of the world with iron and steel, at the lowest rates, in favour of this country.

Coal assumes, in many instances, the form of anthracite, and although the South Wales district contains large deposits of this mineral fuel, comparatively little use has been hitherto made of it for smelting purposes. When raw anthracite is used in the blast furnaces mixed with coke, it has been found that the amount so used should be limited to from 10 to 15 per cent., or the furnace is apt to become choked by an accumulation of decrepitated anthracite. At Creusot, in France, this difficulty was overcome many years ago, by crushing the anthracite coal, mixing it intimately with crushed binding coal, and coking a mixture of about equal proportions in Appold's vertical coke ovens. The result is a somewhat unsightly, but exceedingly hard and efficacious coke. A similar method has been followed for some time in South Wales, where coke is now produced, containing as much as 60 per cent. of anthracite, bound together by 35 per cent. of binding coal, and a further admixture of 5 per cent. of pitch or bitumen, the whole of the materials being broken up and intimately mixed in a Carr's disintegrator prior to being coked in the usual manner. Coke of this description possesses great power of endurance in the furnace, and is worthy the attention of iron smelters.

In the United States of America, anthracite plays a most important part, being in fact the only mineral fuel in the Northern States east of the Alleghany mountains. Its universal application for blast furnaces, for heating purposes, and for domestic use,

imparts to the eastern cities of the United States a peculiar air of brightnesss, owing to the entire absence of smoke, which must impress every visitor most agreeably, and the difference of effect produced by the general use of this fuel, as contrasted with that of bituminous coal, is most strikingly exemplified in a short day's journey from Philadelphia, the capital of the anthracite region, to Pittsburg, the centre of application of bituminous coal.

In visiting lately the deposits of anthracite coal of the Schuylkill district, I was much struck with their vastness, and with the manner and appliances adopted for working them. The American anthracite is less decrepitating than ours, but its successful application to its various purposes is the result chiefly of the judicious manner in which it is prepared for the market. The raw anthracite as it comes from the mine is raised to the top of a wooden structure some 60 to 70 feet high, in descending through which it is subjected to a series of operations of crushing, dressing, sieving, and separating of slaty admixtures, and is then delivered through separate channels into railway wagons, as large-coal, egg-coal, walnut-coal, and pea-coal, each kind being nicely rounded and uniform in size. The dust coal, which amounts to nearly one-half of the total quantity raised, is at present allowed to accumulate near the mine, but experiments are now being carried out to utilise this also for steam-boiler purposes.

Next in importance to mineral fuel, properly speaking, come lignite and peat, of which vast deposits are met with in most countries. These may be looked upon as coal still in course of formation, and the chief drawback to their use, as compared with that of real coal, consists in the large percentage of water which they contain rendering them inapplicable, in their crude condition, to the attainment of high degrees of heat. These difficulties may be overcome by subjecting the wet material to processes of compression, dessication, and coking, whereby excellent fuel and products of distillation are obtained; but the cost of their production has hitherto exceeded their market value. Crude air-dried peat has, however, been rendered applicable for obtaining high degrees of heat such as are required for metallurgical operations, by means of the regenerative gas furnace; and it is important to observe that the calorific value of a ton of air-dried peat or lignite,

if used in this manner, is equal to that of a ton of good coal, if in both cases deduction is made of the percentage of moisture and earthy matter. The carbonaceous constituents of peat yield indeed a very rich gas suitable for melting steel or for re-heating iron, the only precaution necessary being to pass the gas from the producer over a sufficient amount of cooling surface to condense the aqueous vapour it contains, before its arrival at the furnace. This precaution is not necessary, however, in dealing with some of the older lignites, such as occur abundantly in Austria and Hungary, and which may be ranked as almost equal in value with real coal, except for blast furnace purposes.

Fuel also occurs naturally in the gaseous condition, a fact but too well known to every practical coal miner. Occasionally, however, it is found separated from the coal with which it may have been primarily associated, and in those cases it has been made practically available as fuel. At Bakoo, on the Caspian Sea, natural gas has issued spontaneously from the ground for centuries past, and the column of perpetual fire thus produced, has served the purpose of giving the Parsees a holy shrine at which to worship their deity. In the district of Pennsylvania, a more substantial application has been made of the gas issuing from many of the borings, which serves as fuel for working pumping machinery and as illuminating gas for the district. The quantity of gas issuing from some of these wells may be judged from the fact, that one of them, after discharging for three years as much gas as could escape into the atmosphere under a pressure estimated at not less than 200 lbs. on the square inch, has lately been connected by means of a 5-inch pipe with Pittsburg (a distance of 18 miles), where 70 puddling and re-heating furnaces are worked entirely by the fuel so supplied. But even this result furnishes only an imperfect idea of the calorific power represented by this single issue of natural gas, inasmuch as the combustion is carried on in these furnaces on the most wasteful plan, the gas being mixed imperfectly with cold air, and converted to a large extent into dense masses of smoke. An analysis of this gas gives—

Hydrogen	13·50
Marsh Gas	80·11
Ethylene	5·72
Carbonic acid	0·66

The use of natural gas is not likely to assume very large proportions owing to its rare occurrence, but its application at Pittsburg has forcibly reminded me of a project I had occasion to put forward a good many years ago, namely, to erect gas producers at the bottom of coal mines, and by the conversion of solid into gaseous fuel, to save entirely the labour of raising and carrying the latter to its destination. The gaseous fuel, in ascending from the bottom of the mine to the bank, would (owing to its temperature and low specific gravity), acquire in its ascent an onward pressure sufficient to propel it through pipes or culverts to a considerable distance, and in this way it would be possible to supply townships with heating gas, not only for use in factories, but, to a great extent, for domestic purposes also. In 1869, a company, in which I took a leading interest, was formed at Birmingham, under the sanction of the Town Council, to supply the town of Birmingham with heating gas at the rate of 6d. per 1,000 cubic feet, but the object was defeated by the existing Gas Companies, who opposed their bill in Parliament, upon the ground that it would interfere with vested interests. I am still satisfied, however, that such a plan could be carried out with great advantage to the public; and although I am no longer specifically interested in the matter, I would gladly lend my aid to those who might be willing to realise the same.

Fuel also occurs naturally in the liquid state, and if mineral oils could be obtained in quantities at all comparable to those of solid fuel, liquid fuel would possess the advantages of great purity and high calorific value; but, considering its rare occurrence, and comparatively high price, even in the oil districts of Pennsylvania and Canada, its use, for smelting purposes, need not be here considered.

According to the general definition of fuel given above, we have to include the evaporative effect of the sun's rays, by which sea water is raised to elevated mountain levels, whence it descends towards the sea, and in so doing is capable of imparting motion to machinery.

This form of fuel, which takes the place of the coal otherwise expended in raising steam, has been resorted to in all countries since the dawn of civilization, and it is owing to this circumstance that the industries of the world were formerly very much scattered

over the valleys and gorges of mountainous districts, where the mountain stream gave motion to the saw mill or flour mill, to the trompe of the iron smelter, and to the helve of the iron and steel manufacturer.

The introduction of the steam engine, towards the end of last century, changed the industrial aspect of the world in causing manufactories to be massed together in great centres, and this tendency has been still further augmented in consequence of the construction of canals and railways, which enable us to bring together the raw material, and to disperse the manufactured product at a comparatively low cost. It is not unreasonable, however, to expect that a certain reaction in this process of centralization will gradually take place, because, in consequence of ever-increasing competition, the advantage of utilising natural forces, which we could afford to neglect during a period of general prosperity, becomes again an essential element in determining the very lowest price at which our produce may be sent into the market.

The advantage of utilising water-power applies, however, chiefly to Continental countries, with large elevated plateaus, such as Sweden and the United States of America, and it is interesting to contemplate the magnitude of power which is now for the most part lost, but which may be, sooner or later, called into requisition.

Take the Falls of Niagara as a familiar example. The amount of water passing over this fall has been estimated at 100 millions of tons per hour, and its perpendicular descent may be taken at 150 feet, without counting the rapids, which represent a further fall of 150 feet, making a total of 300 feet between lake and lake. But the force represented by the principal fall alone amounts to 16,800,000 horse-power, an amount which, if it had to be produced by steam, would necessitate an expenditure of not less than 266,000,000 tons of coal per annum, taking the consumption of coal at 4 lbs. per horse-power per hour. In other words, all the coal raised throughout the world would barely suffice to produce the amount of power that continually runs to waste at this one great fall. It would not be difficult, indeed, to realize a large proportion of the power so wasted, by means of turbines and water-wheels erected on the shores of the deep river below the falls, supplying them from races cut along the edges. But it would be

impossible to utilize the power on the spot, the district being devoid of mineral wealth, or other natural inducements for the establishment of factories. In order to render available the force of falling water at this, and hundreds of other places similarly situated, we must devise a practicable means of transporting the power. Sir William Armstrong has taught us how to carry and utilize water-power at a distance, if conveyed through high-pressure mains, and at Schaffhausen, in Switzerland, as well as at some other places on the Continent, power is conveyed by means of quick-working steel ropes passing over large pullies; by these means, it may be carried to a distance of one or two miles without difficulty. Time will probably reveal to us effectual means of carrying power to great distances, but I cannot refrain from alluding to one which is, in my opinion, worthy of consideration, namely, the electrical conductor. Suppose water-power to be employed to give motion to a dynamo-electrical machine, a very powerful electrical current will be the result, which may be carried to a great distance, through a large metallic conductor, and then be made to impart motion to electro-magnetic engines, to ignite the carbon points of electric lamps, or to effect the separation of metals from their combinations. A copper rod 3 in. in diameter would be capable of transmitting 1,000 horse-power a distance of say 30 miles, an amount sufficient to supply one quarter of a million candle power which would suffice to illuminate a moderately sized town.

The use of electrical power has sometimes been suggested as a substitute for steam power, but it should be borne in mind that so long as the electric power depends upon a galvanic battery, it must be much more costly than steam power, inasmuch as the combustible consumed in the battery is zinc, a substance necessarily much more expensive than coal; but this question assumes a totally different aspect if in the production of the electric current a natural force is used which could not otherwise be rendered available.

The force of the wind is another source of natural power representing fuel according to the general definition above given, which, though large in its aggregate amount, is seldom used, except in navigation, owing to its proverbial uncertainty. On this account we may dismiss it from serious consideration until our stores of mineral wealth are well nigh exhausted, by which time

our descendants may have discovered means of storing and utilising it in a manner entirely beyond our present conceptions.

Processes.—Having thus dwelt—too long, I fear, for your patience—upon the subject of fuel, I now approach the question as to the processes by which we can best accomplish our purpose of converting the crude iron ore into such materials as leave our smelting works and forges.

The subject of blast furnace economy has already been so fully discussed by you, during the term of office of your past President, Mr. I. Lowthian Bell, M.P., F.R.S., who has done so much himself to throw light upon the complicated chemical reactions which occur in the blast furnace, that I may be permitted, on the present occasion, to pass over this question, and to call your attention more particularly to those processes, by which iron is made to attain its highest qualities both as regards power of resistance and ductility.

Iron and Steel were known to the ancients, and are referred to in their writings, but we have no account of the processes employed in the manufacture of these metals until comparatively-speaking recent times. Aristotle describes steel as purified iron, and says that it is obtained by remelting iron several times, and treating it with various fluxes; we are hence led to suppose that in Aristotle's time steel was made by careful selection, and treatment of steely iron, which latter was produced by something analogous to the Catalan process.

A method referred to by ancient authors, is to bury iron in damp ground for some time, and then to heat and hammer it. Another process first described in Biringuccio's "Pyrotechnology," one of the earliest works on Metallurgy, and later in Agricola's "De Re Metallica," both published in the 16th century, is to retain malleable iron for some hours in a bath of fused cast iron, when it becomes converted into steel. Reaumur, in 1722, produced steel by melting three parts of cast iron with one part of wrought iron (probably in a small crucible) in a common forge, but he failed to produce steel in this manner upon a working scale.

A similar method of producing steel to that proposed by Réaumur has been employed in India for ages, the celebrated Wootz steel being the result of partial or entire fusion of steely iron and carbonaceous matter, in small crucibles arranged in a primitive air

furnace, followed by a lengthy exposure of the ingots to heated air in order to effect a partial decarburization.

In 1750, Hasenfratz refers, in his "Siderotechnic," to three processes for producing steel; melting broken fragments of steel with suitable fluxes, fusing malleable iron with carbonaceous matter, and so treating cast iron (probably with oxides) as to obtain cast steel directly from it.

The credit of producing cast steel upon a working scale is due to Huntsman, who was the first to accomplish its entire fusion in crucibles, placed amongst the coke of an air furnace, which fluid metal he poured into metallic moulds. This process is still carried on largely at Sheffield for the production of special qualities of steel, such as tool steel, tyre steel, castings and forgings, and a ton of cast steel in ingots is produced with the expenditure of from 2½ to 3 tons of Durham coke, according to the degree of mildness of the metal desired.

At Pittsburg, where pot-melting is employed on a considerable scale, plumbago pots having nearly double the capacity of the Sheffield clay pots are invariably used; 18 or 24 of these pots, each containing about a hundredweight of metal, are placed in a gas furnace, and each pot lasts twenty-four hours yielding five charges during that interval. The fuel consumed amounts to one ton of small slack per ton of steel melted, which is delivered to the works at the surprisingly low price of 30 cents per ton. With these important advantages in his favour, the American steel melter should be able, one would think, to meet without protection his Sheffield competitor in the open market.

With regard to Bessemer steel, great advances have been made in recent times in cheapening its production. At Creusot and other Continental works, a system of direct working, or of transferring the pig metal in the molten condition from the blast furnace to the Bessemer converter, has been introduced, and the same method has been recently adopted at several of the leading English works. By this method of working, the fuel usually employed in re-melting the pig metal in the cupola (say 2½ cwt. per ton) is clearly saved; and other advantages are realized, but, on the other hand, the Bessemer converter is made dependent upon the working of the blast furnace both as regards time and the quality of the resulting

metal. At Barrow and other large works, where a number of blast furnaces supply several Bessemer converters, in addition to pig metal, for the open market, this mode of working appears to be practically free from the objection above stated, and a hot ladle, with its engine, may be kept steadily at work transferring the pig metal from one blast furnace or another to the converters. But it still remains to be seen whether any practical advantage can be realized by this method of working at smaller works, where a change in the working of the blast furnace from Bessemer to forge pigs would cause a serious interruption in the working of the Bessemer plant.

In America, the effort of the ironmaster has been directed—chiefly under the guidance of Mr. A. L. Holley—towards a saving of labour, by increasing to an almost incredible extent the number of blows per diem from each converter. Thus I was informed that at the North Chicago Steel Works, as many as 73 blows had been obtained in one pit in 24 hours, although I have reason to doubt whether this rate of working could be maintained for any length of time. The Americans have not adopted, so far as I could ascertain, the direct process of working, but are content to remelt their pig metal in large cupolas in immediate proximity to the converters; the capacity of the converters has latterly been much increased, and the degree of heat engendered by a blast of increased power, has been augmented to such an extent that a considerable amount of scrap metal can be re-melted within the fluid bath before discharging the same into the ingot moulds.

Whilst the Bessemer process has been making rapid strides, another process has gradually grown up by its side, which I cannot pass over without remark. I allude to the open-hearth steel process, with which my name and the joint names of Siemens and Martin are associated. The conception of this process is really as old as that of cast steel itself. The ancient Indian steel, the Wootz, was the result of a fusion of a mixture of malleable iron and carbon. Réaumur, as already stated, proposed to melt wrought iron and pig metal together for, the production of steel, as early as 1722; and J. M. Heath,—to whom we owe the important discovery that by the addition of manganese to cast steel its malleability is greatly increased,—endeavoured to realize the conception of

producing steel in large masses upon the open hearth of the furnace in the year 1839, and he again has been followed in these endeavours by Gentle Brown, Richards, and others in the same direction.

When, in 1856, I first seriously gave my attention, in conjunction with my brother (Frederick Siemens) to the construction of a regenerative gas furnace, I perceived that this furnace would be admirably adapted to the production of steel upon the open hearth, and I remember proposing it for such a purpose to Mr. Abraham Darby, of Ebbw Vale, in 1861. Ever since that time I have been engaged in the realization of this idea, which has been retarded, however, by those untoward circumstances which ever intervene between a mere conception and its practical realization. Although two of my earlier licensees, Mr. Chas. Attwood, of Tow Law, and the Fourchambault Company, in France (with whom was my esteemed friend, the late M. Lechatelier, Inspecteur-General des Mines), succeeded, in 1865 and 1866, in producing steel upon the open hearth, they did not persevere sufficiently to attain commercial results; and it was not until after I had established experimental steel works at Birmingham, that I was enabled to combat in detail the various difficulties which at one time looked well-nigh insuperable.

Whilst thus engaged, Messrs. Pierre and Emile Martin, of Sireuil, who had obtained licenses for furnaces to melt steel both in pots and on the open hearth, succeeded, after a short period of experimenting, in introducing into the market open-hearth steel of excellent quality.

Messrs. Martin gave their attention to the production of steel by the dissolution of wrought iron and steel scrap in a bath of pig metal, whilst my own efforts were more especially directed to the production of steel by the use of pig metal and iron ores, either in the raw state, or in a more or less reduced condition, which latter process is the one mostly employed in this country.

One of the advantages that may be claimed for the open-hearth process consists in its not being dependent upon a limited time for its results. The heat of the furnace is such that the fluid bath of metal, after being reduced to the lowest point of carburization, may be maintained in that condition for any reasonable length of time, during which samples can be taken and tested, and additions

either of pig metal, of wrought scrap, spongy metal, or ore, may be made to it so as to adjust the metal to the desired temper. The requisite proportion of spiegeleisen, or ferro-manganese, is then added in the solid condition, and the result is a bath of metal, the precise chemical condition of which is known, and which has the advantage, if properly managed, of being what is technically called "dead melted." This circumstance renders it applicable for certain purposes for which pot steel has hitherto been mostly employed.

The purpose to which the open-hearth process is more especially applicable is for the conversion of scrap steel, and iron of every description into steel or ingot metal, and it is now used, indeed, to a large extent for the conversion into steel of old iron rails. The wearing qualities of these converted rails have been under test since 1867, when the Great Western Railway Company had some old Dowlais iron rails converted into steel at my Experimental Steel Works at Birmingham, which was rolled into rails by Sir John Brown & Co.; these have been down ever since that time at Paddington, subjected to great wear and tear.

The manufacture of steel, both by the Bessemer and the open-hearth processes, is much facilitated by the use of ferro-manganese. This material was introduced into the market in 1868, by Mr. Henderson, of Glasgow. It was produced successfully by charging carbonate or oxide of manganese, and manganiferous iron ore intimately mixed with carbonaceous matter upon the open-hearth of a Siemens furnace with a carbonaceous lining; but the demand for this material was not sufficient to render the manufacture profitable at that time, and it was not until the year 1875 that it was re-introduced into the market by the Terrenoire Company.

Manganese, when added in a proportion of ·5 per cent., or more, to steel or ingot metal, containing only from ·15 to ·20 per cent. of carbon, has the effect of removing red-shortness, and of making it extremely malleable both in the heated and cold conditions. In using spiegeleisen containing only from 10 to 15 per cent. of metallic manganese, it is impossible to supply the amount necessary to produce this malleability without adding, at the same time, such a percentage of carbon as would produce a hard metal. The use of ferro-manganese enables us to overcome this difficulty, and

greatly facilitates the production of a metal so malleable and with so little carbon, as to remain practically unaffected in its temper when plunged red-hot into water.

Another result produced by the use of manganese without carbon, upon mild steel or ingot metal, is to neutralize the objectionable effect of phosphorus, so long as the latter does not exceed the limit of ·25 per cent. This metal, in which phosphorus may be said to take the place of carbon, presents a large specular fracture, and is, contrary to what might have been expected, extremely ductile when cold.

Iron when in the fluid condition can be alloyed with other metals, and some of the compounds thus formed are known to possess very remarkable properties. Thus, iron combined with 3 per cent. of Tungsten and ·8 per cent. of Carbon, yields a metal which can be worked like ordinary steel, but which, when hardened, retains magnetism to a very remarkable degree, a property which was discovered by Dr. Werner Siemens in 1853. A further addition of Tungsten produces an exceedingly hard metal (introduced into the market by Mr. Mushet in 1868) which cannot be forged, but which when cast into bars, and ground so as to form a sharp edge, produces cutting tools capable of great endurance.

An admixture of Chromium has for many years past been known to produce steel of great hardness and strength, but it is only quite recently that it has been brought into practical use in America by by Mr. Julius Baur, and has been taken up in this country by Sir John Brown and Co., of Sheffield, who claim for it very remarkable properties as regards strength, malleability, and freedom from corrosion.

The formation of compounds such as these is a matter of great interest in connection with the future development of the applications of steel, and is one of those subjects which I venture to suggest might be much advanced by an organized research, under the auspices of a Committee of the Iron and Steel Institute.

The value of the material known as mild steel or ingot metal, consists in its extreme ductility under all possible conditions. Its ultimate strength is much inferior to that of ordinary steel, and rarely exceeds 28 tons per square inch; its limit of elasticity is reached at 15 tons per square inch, whilst the limit of elasticity

of a harder steel may reach from 25 to 30 tons per square inch, and that of hard drawn steel wire from 45 to 50 tons. But in estimating the relative value of these different materials by the amount of work that has to be expended in causing rupture, it will be found that the mild steel has the advantage over its competitors. When subjected to blows or sudden strains, such as are produced by the explosion of gun cotton or dynamite, extra mild steel differs in its behaviour from that of BB iron and ordinary steel, by yielding to an extraordinary extent without fracturing, and it is in consequence of this non-liability to rupture that it may be loaded to a point much nearer to its limit of elasticity than would be safe with any other material.

Attention has been recently directed in various quarters to remedy defects appertaining to steel, viz., piping and showing honey-combed appearance in the ingot. It is well known that if such steel is hammered and rolled, the open spaces contained in it are elongated, and seemingly closed up, but in reality continue to form severances within the metallic mass, to the prejudice of the uniform strength of the finished forging.

In casting steel containing more than ·5 per cent. of carbon, the defect of honey-combing can easily be avoided if care is taken to have the metal "dead melted" before pouring it into the mould; and that of piping by continuing the inflow of fluid metal for a sufficient length of time while it is setting. But in dealing with mild steel containing only say ·2 per cent. of carbon, the difficulty of making a sound casting is greatly increased. Much may be done, however, by careful manipulation of the fluid metal, and by the judicious addition to it of manganese or other oxidizable metals, such as silicon or lead, by which occluded oxygen is removed.

Sir Joseph Whitworth, who, as you well know, has given much attention to this subject, has overcome the evil mechanically by subjecting the steel, while setting in the mould, to great hydraulic compression. He has thus succeeded in producing, in large masses, mild steel of extremely uniform strength, and the only doubt which could possibly be raised against the advisability of producing fluid steel for ordinary applications by this method is founded on considerations of cost.

The subject of producing sound steel castings is one which we

shall have an opportunity to discuss in reference to a paper which will be presented by M. Gautier.

Applications of Steel.—The employment of steel for general engineering purposes dates only from the year 1851, when Krupp, of Essen, astonished the world by his exhibits of a steel ingot weighing 2,500 lbs., and of his first steel gun, and introduced a comparatively mild description of pot steel for steel tyres, axles, and crank shafts. For the production of these he constructed his celebrated monster hammer, with a falling weight of 45 tons, which, at that time, far surpassed in magnitude and power our boldest conception, and is now only being exceeded by a still more powerful hammer in course of erection at the Essen Works. Krupp's steel was, however, not cheap steel, and it is to our past president, Mr. Henry Bessemer, and to the important addition made to his process by Mr. Mushet, that we are indebted for the production of steel at such a reduced cost as to make it available for railway bars and structural purposes in substitution for iron, since which event the applications of this superior material show a most extraordinary rate of increase. Not only do we travel upon steel tyres, running over steel rails, but, at least one of our leading railway companies, the London and North Western, has, under the able management of Mr. F. W. Webb, constructed as many as 748 locomotive engines, including boiler, frame, and working parts, entirely of that material, excepting only the fire boxes which are still made of copper. In France, also, much attention has been given to the introduction of steel for machinery purposes, and there, as well as in the United States, Germany, and Holland, that material is used largely in the construction of bridges and other engineering works.

In this country the application of steel for structural purposes has occupied the attention of some of our leading civil engineers for many years, and Sir John Hawkshaw, when called upon to construct a railway bridge, at Charing Cross, in 1859, proposed the use of steel in order to lighten the structure. He was prevented, however, from carrying his idea into effect by the rules of the Board of Trade, which provide that wrought material of any kind shall not be weighted either in compression or extension to more than 5 tons per square inch. Repeated efforts have been made since that time to induce the Board of Trade to adopt a new rule, in

which the superior strength of steel should be recognized, and in order to facilitate their action a committee was formed, consisting of Mr. William Henry Barlow, Capt. Galton, and others, who carried out—with the pecuniary aid of leading steel manufacturers —a series of valuable experiments, showing the limit of elasticity and ultimate strength of various steels. The results obtained are published separately in "Experiments on the Mechanical and other Properties of Steel by a Committee of Civil Engineers."

At the instance of Mr. Barlow, the British Association appointed a further Committee to promote the object of obtaining for steel its proper recognition, and this has led finally to the appointment under the sanction of the Board of Trade of three gentlemen, viz., Sir John Hawkshaw, F.R.S., and Mr. William Henry Barlow, F.R.S. (who were nominated by the Council of the Institution of Civil Engineers), and of Colonel Yolland, F.R.S., of the Board of Trade, who have agreed upon a report recommending the use of steel as a building material, subject to a limit of strength greatly in excess of the limit assigned to wrought iron. It is to be hoped that the Board of Trade, by adopting that report, will remove the serious drawback which has too long stood in the way of the application of steel for structural purposes, and which has rendered the construction of large works, such as the projected bridge over the Frith of Forth practically impossible.

As regards the construction of ships of extra mild steel, the English Admiralty, following the example set by France, has, under the advice of Mr. Barnaby, the Chief Constructor, taken the lead of the commercial navy of the Country, and several corvettes have recently been constructed entirely of that material at the Government Yard at Pembroke, and upon the Clyde. The constructors of merchant shipping have hitherto been restricted by rules laid down by Lloyd's Registry, which make no distinction between common iron and steel in determining the classification of a vessel. It is to be hoped that the important engineering and shipbuilding interests of the country will soon be released from regulations which may have been well adapted to the use of an inferior material such as common iron, but fail entirely to meet the requirements of the present day.

In shipbuilding, the use of a material superior in toughness and

in strength produces the double advantage of greater safety to life and property, and of an increase of carrying capacity to the full amount of weight saved in the construction of the ship. It should be borne in mind that this additional weight of merchandise is carried without increasing the working expenses of the ship and power required in its propulsion, and may just suffice to strike the balance between working a vessel designed for long voyages at a fair profit or at a loss. In constructing the masts and yards of vessels of the stronger material, the weight saved is a matter of still greater importance, and I am glad to say that this question now engages earnest attention.

In the United States, a committee, composed of both military and civil engineers, have been engaged for some time upon the subject of determining experimentally the structural value of iron and steel. This Committee have the advantage of substantial support from the United States Government, who, after a first grant of 75,000 dollars, have, I observe, voted a further sum of 40,000 dollars in aid of the experimental enquiries which have been instituted.

The Council of the Iron and Steel Institute are not unmindful of the importance of this subject, and have invited those gentlemen of this and other countries, who have given most attention to the production and application of steel, to aid us in our forthcoming discussion with the results of their experience.

In the course of this discussion, the distinctive limits between steel and iron will necessarily engage your attention. Considering the extraordinary change of physical condition which iron undergoes when alloyed with small percentages of carbon, manganese, phosphorus, tungsten, chromium, and other substances, and considering, further, that it is never quite free from some admixture, the question of nomenclature is one naturally surrounded with difficulty, but it is becoming one of considerable practical importance, when rules are to be laid down regulating the permissible strength of different grades of these materials.

Dr. Percy has, in his "Metallurgy of Iron and Steel," defined steel as iron containing a small percentage of carbon, the alloy having the property of taking a temper, and this definition is subsantially equivalent to those found in the works of Karsten, Wedding, Grüner,

and Tunner; on the other hand, Messrs. Jordan, Greiner, Gautier, Phillipart, Holley, and others, define as steel all alloys of iron which have been cast and are malleable, whilst Sir Joseph Whitworth considers that steel should be defined mechanically by a co-efficient representing the sum of its strength and ductility.

With the object of settling this question of nomenclature, an International Committee was appointed at Philadelphia, by the Institution of American Mining Engineers. The Committee consisted of the following gentlemen:—Mr. I. Lowthian Bell, M.P.; Dr. Hermann Wedding; Professor Tunner; Professor Åkermann; M. Grüner; Mr. A. L. Holley, and Mr. T. Egleston, and they resolved upon the following recommendation:—

"I. That all malleable compounds of iron, with its ordinary ingredients, which are aggregated from pasty masses, or from piles, or from any form of iron not in a fluid state, and which will not sensibly harden and temper, and which generally resemble what is called wrought iron, shall be called Weld-iron (German Schweiss-eisen; French, Fer-soudé.)

II. That such compounds when they will from any cause harden and temper, and which resemble what is now called "puddled steel," shall be called Weld-steel (German, Schweiss-stahl; French, Acier-soudé.)

III. That all compounds of iron, with its ordinary ingredients, which have been cast from a fluid state into malleable masses, and which will not sensibly harden by being quenched in water while at a red heat, shall be called Ingot-iron (German, Fluss-eisen; French, Fer-fondu.)

IV. That all such compounds, when they shall from any cause so harden, shall be called Ingot-steel (German, Fluss-stahl; French, Acier fondu)."

The nomenclature here proposed is entitled to careful consideration from the eminence for both theoretical and practical knowledge of the gentlemen composing the committee; but I apprehend that, for common use, the distinctions desired to be drawn are too manifold. Moreover, the lines of demarcation laid down run through materials very similar, if not identical, in their application, where a distinction in name would be extremely difficult to maintain, and awkward to draw. Take, for instance, railway bars from Ingot-

metal, which are usually specified to bear a given dead load without deflecting beyond certain limits, and to resist a certain impact without rupture. The materials answering to these requirements contain from ·2 to ·6 per cent. of carbon, depending in a great measure upon the mode of production, and upon the amount of admixture of phosphorus, sulphur, silicon, and manganese. But inasmuch as the quality of tempering is chiefly due to carbon, part of the rails delivered under such specification might have to be classified as ingot-iron, and part as ingot-steel. The Committee omits to define the degree of hardening which it considers necessary to bring a material within the denomination of ingot-steel; it is well known, however, that the temper depends upon the exact temperature to which the metal is heated before being plunged into the refrigerating medium, and also upon the temperature and conductivity of the latter, and that ingot metal with only ·2 per cent. of carbon, when plunged hot into cold water, takes a certain amount of temper. The question of the amount of import duties payable in foreign countries upon metal occupying a position near the proposed boundary line, would also lead to considerable inconvenience.

Difficulties such as these have hitherto prevented the adoption of any of the proposed nomenclatures, and have decided engineers and manufacturers in the meantime, to include, under the general denominations of cast steel, *all compounds consisting chiefly of iron, which have been produced through fusion, and are malleable.* Such a general definition does not exclude from the denomination of steel, materials that may not have been produced by fusion, and which may be capable of tempering such as shear steel, blister steel, and puddled steel,nor does it interfere with distinctions between cast steels produced by different methods, such as pot steel, Bessemer steel, or steel by fusion on the open hearth. The forthcoming discussion will, I hope, lead to some general agreement regarding this question of nomenclature.

Wrought Iron.—While steel is gradually supplanting wrought iron in many of its applications, efforts are being made to maintain for the latter material an independent position, for cheapness and facility of manipulation, by improving the puddling process.

Mechanical puddling, like many other important inventions, has

taken a long time for its development, and has engaged the attention of many minds, but I will only here mention the names of Tooth, Yates, and Mr. Menelaus, our past President, who have pioneered the road; and of Danks, Spencer, Crampton, and others who have followed more recently in the same direction. It is chiefly owing, however, to the persevering endeavours of Mr. Heath, and of Messrs. Hopkins, Gilkes, & Co., that the mechanical puddling of pig metal has been accomplished with a considerable amount of success.

All these efforts have had reference to puddling in a chamber rotating upon a horizontal axis, but numerous attempts have also been made to accomplish mechanical puddling by the introduction into stationary chambers of rabbles moved by mechanical power, and by the use of chambers rotating upon an inclined axis, in connection with which latter, the names of Maudsley, Sir John Alleyne, and Pernot, should be mentioned. The principal difficulty connected with the rotatory puddling furnace consists in providing a lining of sufficient power to resist the corrosive action produced by siliceous slags, and it is important therefore, that the pig metal introduced into the rotative puddler should be as free from silica as possible. By charging fluid metal into the furnace, the silica adhering to the pigs in the form of sand is got rid of; but efforts have latterly been made, with satisfactory results, I believe, to subject the pig iron itself to a simple finery process on its way from the blast furnace to the rotative puddler, with a view of removing the silicon chemically combined with the pig. M. Hamoir, of Belgium, has been engaged upon this subject for some years, as you will have seen from the "Report on the Progress of the Iron and Steel Industries in Foreign Countries" in our JOURNAL, while in this country, Mr. I. Lowthian Bell has called the Bessemer converter into requisition for effecting the desired object.

We are informed that not only does the lining of the furnace stand better in using this semi-refined metal, but that the yield per furnace per diem, as well as the quality of the metal obtained, are much improved.

It is intended to roll the metal thus produced into railway bars, without any intermediate process of re-heating, and to subject the rails to a process of case-hardening similar to what was practised

some years ago by Mr. Dodds, in South Wales. The case-hardened iron rails are expected to rival steel rails in quality, but it remains to be seen whether their wearing properties will not be obtained at the cost of brittleness, and whether rails manufactured by this method will be able to compete in price with steel rails.

Three years ago, I had the honour of bringing before this Institute a plan of producing wrought iron directly from the ore, in a rotative furnace of special construction, and heated by gas. This process was at that time only carried on upon a small scale at my Sample Steel Works, in Birmingham. It has since been carried out upon a working scale, at Towcester, and in Canada, and although the results hitherto obtained cannot yet be considered entirely satisfactory from a commercial point of view, I see no reason to feel discouraged as regards the ultimate result of this method of treating iron ores. By it, iron of almost entire freedom from sulphur and phosphorus is obtained from ores containing a considerable percentage of these impurities. If steel is to be produced, the raw balls, as they leave the rotatory furnace, are either immediately transferred to the bath of the open-hearth furnace, or are previously subjected to the processes of squeezing and hammering for the removal of scoria, which otherwise carries some of the impurities contained in the ore into the metallic bath, and prevents the attainment of steel of a high quality.

One of the drawbacks to the use of iron and steel for structural purposes is found in their liability to rust when exposed to air and moisture. The ordinary means of protection against rust consists in covering the exposed surfaces with paint, and if this is renewed from time to time, iron or steel may be indefinitely preserved from corrosive action. Another mode of protection consists in dipping articles of iron and steel while hot into a bath of oil, when some of the oil penetrates to a slight depth into the pores of the metal, while other portions become decomposed, and form a very tenacious resinous coating. For the protection of iron and steel, when in the form of thin sheets or wire, galvanizing, as is well known, is largely resorted to.

The protection in this case depends upon the fact that zinc, although more oxidisable than iron, forms, with oxygen, an oxide of a very permanent nature which continues to adhere closely to

the metal, and thus prevents further access of oxygen to the same. This mode of protection presents the further advantage that so long as any metallic zinc remains in contact with the iron in presence of moisture, the latter metal forms with the zinc the negative element of an electrolytic couple, and is thus rendered incapable of combining with oxygen.

Galvanising is not applicable in those cases in which structures of iron and steel are put together by the aid of heat, or are brought into contact with sea water, which would soon dissolve the protecting zinc covering. But even in these cases the metal may be effectually protected against corrosion by attaching to it pieces of zinc, which latter are found to dissolve in lieu of the iron, and must, therefore, be renewed from time to time.

Captain Ainslie, of the Admiralty, has lately made a series of valuable experiments, showing the relative tendency towards corrosion of both iron and steel when in contact with sea water, and of the efficacy of pieces of zinc in preventing this corrosion. These experiments further show that mild steel is—contrary to the results obtained by M. Gautier—more liable to corrosion than wrought iron in its unprotected condition, but that zinc acts most efficaciously in protecting it.

Quite recently, another mode of protecting iron and steel plates from corrosion has been suggested by Professor Barff. This consists in exposing the metallic surfaces, while heated to redness, to the action of superheated steam, thus producing upon their surface the magnetic oxide of iron, which, unlike common rust, possesses the characteristic of permanency, and adheres closely to the metallic surface below. In this respect it is analogous to zinc oxide adhering to and protecting metallic zinc, with this further advantage in its favour, that the magnetic oxide is practically insoluble in sea water and other weak saline solutions. Time will show to what extent this ingenious method of protecting iron and steel can be made practically available.

Before concluding this address, I wish to call your attention to a matter which will require your early consideration. The Iron and Steel Institute has now attained an influential position, and is likely to increase from year to year in its beneficial action, upon the further development of a trade which may justly be claimed

to be the most important in this country. In order to give additional weight to its action, it seems necessary that its position should be recognised in official quarters, and that it should be possessed of a habitation in a central locality, which should comprise office accommodation, a library, a model room, a lecture room, and laboratory. Such a building, if specially erected for the Iron and Steel Institute, would exceed the means at their disposal for such a purpose, but the moment has arrived when other institutions devoted to the cultivation of different branches of applied science feel the necessity for similar accommodation. Would it not be possible for our Institute to join efforts with those kindred institutions, for the erection of a joint building, representing applied science as completely as Burlington House represents pure science. Such a project could not be realised without the concurrence of the parent institution of applied science, "The Institution of Civil Engineers," whose building, though large, is by no means sufficient for its actual requirements. The new building might, therefore, accommodate the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institution of Naval Architects, the Society of Telegraph Engineers, the Iron and Steel Institute, and possibly other societies which hold their ordinary meetings on different days of the week, and some of them at considerable intervals of time; it would not, therefore, be necessary to provide more than one, or perhaps two, general meeting rooms, and one library, but each society would require separate office accommodation and council chambers, the whole being so arranged as to be able to be thrown open for the holding of *conversaziones*.

The common interests of the societies might be placed under the supervision of a joint House and Library Committee, presided over by the President of the Institution of Civil Engineers, and comprising amongst its members one or two members of councils and the secretaries of the different societies.

The Government would probably not be unwilling to further the realisation of an object of such great usefulness by granting a site in a central portion of the metropolis. Each society might be called upon to furnish a portion of the capital required, either out of its accumulated funds, or by voluntary contributions of its

members, and the remainder could probably be raised upon debentures, and thus become chargeable upon the ordinary subscriptions of future years.

The details of such a scheme would, of course, require most careful consideration; but I believe that the present moment would be favourable for its realisation if you, as well as the other scientific bodies concerned, consider the matter worthy your attention.

The great variety and importance of subjects of interest to our Institution are my apology for having detained you longer than I intended to do in reading this address.

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